TABLE 10.—*Harmonic analysis of rainfall curves; unsmoothed amplitudes.*

PER CENT OF NORMAL FROM MINIMUM TO MAXIMUM.

	Harmonics.				
	First.	Second.	Third.	Fourth.	Fifth.
Eastern Group, whole data	17.2	8.8	10.0	5.2	4.2
First half data, Eastern Group	13.6	9.6	13.6	6.2	10.0
Second half data, Eastern Group	21.0	11.0	6.8	6.7	0.6
Pacific Group	14.0	4.7	13.0	4.3	3.2

UNSMOOTHED PHASES AT EPOCH OF PHASE 1 OF CURVES.

Eastern Group, whole data	39°	83°	114°	251°	234°
First half data, Eastern Group	27	118	105	273	236
Second half data, Eastern Group	47	57	127	219	323
Pacific Group	27	78	138	303	303

SMOOTHED AMPLITUDES, PER CENT OF NORMAL FROM MINIMUM TO MAXIMUM.

Eastern Group, whole data	16.1	6.8	5.6	1.6	0.2
First half data, Eastern Group	13.0	7.3	8.1	1.6	0.4
Second half data, Eastern Group	19.8	8.4	3.6	1.5	0.0
Pacific Group	13.2	4.0	7.0	1.3	0.0

SMOOTHED PHASES AT EPOCH OF PHASE 1 OF CURVES.

Eastern Group, whole data	38°	85°	113°	238°	102°
First half data, Eastern Group	26	118	105	278	302
Second half data, Eastern Group	48	57	128	222	207
Pacific Group	30	80	138	309	313

DISCUSSION.

By C. F. MARVIN.

If we understand Mr. Alter's claims correctly, he embraces the idea advocated by Mr. Clough, namely, that the duration of the sun-spot period is variable; that is, it is systematically lengthened and shortened. With this principle as a basis in conjunction with Wolfer's values of the epochs of sun-spot maxima and minima and by means of a graphic integration represented by his diagram, figure 8, Mr. Alter arrives at the highly variable values of the length from year to year of the sun-spot period beginning about 1847. One-ninth of this period, stated in months, then, becomes the variable length of the alleged cycle in rainfall. By methods, details of which are made clear, the rainfall data of the Weather Bureau for practically the entire United States are analyzed, and Mr. Alter seems convinced that he has hit upon a very important period or cycle, both in sun-spot numbers and also in rainfall sequences in the United States. Acceptance of Mr. Alter's conclusions at once commits one to his claim that he has established as more or less probable that sun spottedness or some related solar activity is at least one factor in the control of United States rainfall.

In order that the reader may be spared any uncertainty of mind, the writer may say frankly, at the outset of this discussion, that he is convinced that little if any thing at all as to a cycle in rainfall or a connection between rainfall and sun-spots is proved by the investigation.

The discussion may proceed under the following topics:

(1) The proposition is irrational.

(2) The quantitative basis of figure 8 (variable length of sun-spot period) is hypothetical and inadequate.

(3) The method of layout of data and computation of results introduces glaring sources of error and uncertainty.

(4) Least square methods, in so far as they are brought to bear on the problem, have a limited significance.

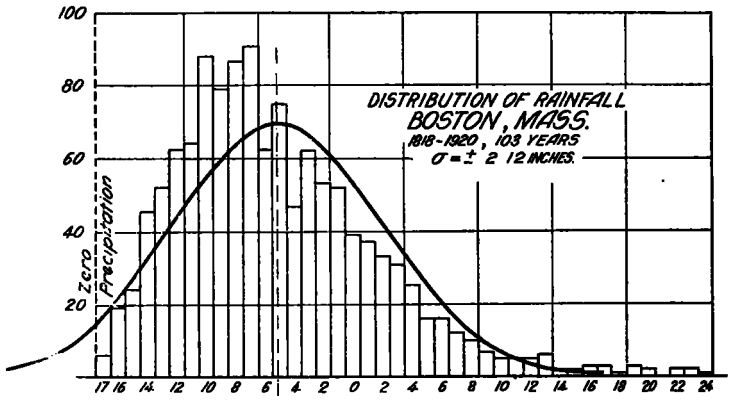
(5) The rainfall data are seemingly heterogeneous.

Only a very brief discussion of these topics is now possible.

(1) *The proposition is irrational.*—A great deal is already known with reference to the definite physical causes of rainfall, its distribution both as to continental area and as to topography, also as to time and the march of seasons. We may fairly say that practically every feature of the occurrence of precipitation, especially within the United States, is intimately associated with the general circulation of the atmosphere and the sequences of cyclones and anticyclones. How can we be convinced that the features which appear in Mr. Alter's results are not very largely or entirely caused by the uneliminated features of rainfall dependent upon the general circulation of the air?

The simple method of tabulation of highly composite data in columns employed by Mr. Alter can not be admitted to exclude and otherwise wholly eliminate extraneous influences, except, possibly, when the number of observations is very great, and even then it must be demonstrated a systematic residual from one cause or another is not included.

There can not be anything unique or magical in a changeable period of time, which shall constantly be



one-ninth of a hypothetically changing sun-spot period. Other integral fractional parts corresponding to the remaining 8 digits, as also many other multiples and submultiples, have an equal claim on our imaginations and on the probabilities and possibilities of the situation. If the reality of any one of these is admitted, on what basis can the others be rejected, and what is the consequence of the acceptance of all? This line of thought leads exactly to the same consequences as when we recognize that any succession of variable values can be *represented* more or less exactly by a Fourier series. It may be demonstrated that the original data are the summation of the several component elements into which they may be analyzed, but this is of no significance whatever as indicating the real physical existence of any or all of the components.

Of course, science is either inductive or deductive. While the absence of an entirely rational cause or explanation of certain assumed or suspected relations does not justify rejection of the hypothesis, nevertheless, on the other hand, purely inductive results, or fragments of results, without a basis of rationality, must necessarily be viewed with skepticism, or their physical reality must be demonstrated by incontrovertible proofs.

(2) *Quantitative basis of figure 8 is inadequate.*—Probably every student of sun-spot data has recognized the

variable length of the period. Newcomb especially has discussed the point, and concluded from his analysis of the data *that the variations in length of period are accidental.* While I believe this conclusion is too extreme, I feel that we are compelled to say now that the numerical data extracted by Mr. Alter from figure 8, and which is basic and fundamental to the whole of his statistical demonstration, are probably very inaccurate, even if the length of the sun-spot period can be so defined as to admit of a concept of the kind depicted graphically in figure 8. This whole question of the variable length of period and the one to be discussed next is so basic to the whole investigation that the conclusions reached seem to be very seriously invalidated.

The tabulation of data in rows and columns in a manner designed to bring into the same columns data of the same "suspected" phase relations is the conventional method of seeking hidden periodicities, and exactly the same method has been used by meteorologists almost for centuries for fixing the values of normals and long-time averages of every element of data. The reality of any specific result can often be finally decided only upon the convincing testimony of a *long record.*

(3) *Sources of error introduced by layout.*—Attempts to apply the summation method to complex data on the supposition that the *length* of a suspected cycle is variable introduces glaring modifying errors *whenever the changing lengths are expressed in fractional parts of the* phase unit (a month in Mr. Alter's case). Rainfall data especially should not be treated in *monthly amounts* in this manner. In such cases resort must be had to actual data of *daily* rainfall, or possibly of weekly, or better, pentad totals. This at least is desirable even in long records, and practically necessary in short records, because the procedure dealing with fractional months is valid only for an indefinitely long record.

Mr. Alter's Table 3 giving the dates for skipping and repeating monthly values in order that his phase units may not get more than half a month out of step with the observed monthly rainfall is a wholly unacceptable scheme for accounting for the changing length of cycle his hypothesis contemplates. A single example will illustrate this.

Table of precipitation fabricated (included by repetitions) and discarded (by skipping) to keep in step, Washington, D. C.

Repeated.			Skipped or averaged.		
Year.	Month.	Amount.	Year.	Month.	Amount.
		Inches.			*Inches.*
1871	April	0.91	1872	April	1.77
			1873	Sept.	3.48
1884	Sept.	.14	1874	Apr., Oct.	5.94
1885	Apr., Oct.	10.40	1875	Mch., Jun., Nov.	7.91
1886	Apr., Sept.	4.50	1876	Feb., May, Aug., Nov.	13.52
1887	Jan., May, Sept.	8.01	1877	Jan., Apr., Jul., Sept., Dec.	22.67
1888	Jan., May, Sept.	14.58			
1889	Feb., Aug.	5.54	1878	Mch., Jun., Aug., Nov.	22.56
			1879	Mch., July, Nov.	6.20
	Total	33.68	1880	Apr., Oct.	6.12
			1881	July	1.67
				Total	91.84
			1893	Apr.	3.12
			1894	May	4.03
			1895	May	3.09
			1896	Apr.	1.07
			1897	Mch.	2.66
			1898	Jan., Dec.	7.10
			1899	Dec.	1.68
			1901	Jan.	2.92
			1902	Apr.	2.22
			1903	Sept.	.74
			1909	July	1.80
			1913	Jan.	2.85
				Total	33.28
				Grand total	125.12

Thus, if we apply Alter's method to the Washington data, for example, we are required to discard or brush aside during the nine years between April, 1872, and July, 1881, a total of 91.84 inches of rainfall just as if it had never fallen or been recorded. Of this amount 45.23 inches are rejected in a short interval of 27 months. Stated in other words, the same result would have been secured if, in the records for the nine years mentioned, the rainfall were missing for the 26 particular months skipped, or were missing for no less than eight months out of the 27 months from September, 1877, to November, inclusive, 1879. The table speaks for itself. It is true Mr. Alter has averaged rather than skipped months where adjustments are necessary. This only modifies but does not remedy the difficulty, and few meteorologists will be satisfied with an investigation in which a feature of this kind is inherent.

As stated, only daily, possibly weekly, tabulations of rainfall may be safely used for the formation of sequences the lengths of which are fractional months. Of course, if a real cycle exists, monthly data may be tabulated in sequences of an integral number of months greater or less than the actual length of the cycle. Then by noting, if possible, the *precession* of phases by methods fully explained in the textbooks a more exact estimate of the length of the cycle is secured.

(4) *Least square methods have a limited significance.*—It is just as important to recognize and guard against the limitations of the laws of probabilities, in dealing with weather phenomena, as it is to appreciate the great value of least square methods and apply them properly in all such investigations. We can touch upon the question here only as it relates to precipitation and the matters in hand. Everyone knows that the laws of probability apply to values and events which exhibit the Gaussian distribution, also that a large number of cases are necessary to define a distribution. It is pretty well known, but too often disregarded, that rainfall, especially, and long records of many other meteorological elements depart very widely from the Gaussian distribution. Consequently the formulae and equations of least squares may seriously fail to express the actual probabilities in matters of precipitation. Figure 1 shows the histogram of monthly precipitation for 103 years for the vicinity of Boston, Mass., also the Gaussian curve of best fit. The skew distribution shown in the figure is well known to be an inherent characteristic of rainfall data. Of course, the feature is entirely independent of the order or succession in which the amounts of precipitation may occur. The same collection of numbers may be mixed up in a bowl and drawn out at random any number of times, but the frequency distribution will remain entirely unaffected. Argument is not needed to show that least square methods and the ordinary probabilities can not be applied to rainfall data with any convincing results, especially to cases involving only a small number of events. In the case of Boston, the probability theory calls for 47 months with imaginary or impossible amounts of rainfall less than nothing. A like number of months should have rainfall greater than about 6.3 inches. In fact, there are 69 such months. Finally, the actual number of months with rain between 0.90 and 3.50 is about 650. The least square theory calls for only 507. This is not the fault of the theory; it is simply misapplication.

(5) *Rainfall data heterogeneous.*—Mr. Alter has discussed by his method the data from practically every State in the Union. A few of the records are fairly long, but most of them are short and with differing initial dates. Some may suppose that this mere bulk of statistics gives weight to his argument. The writer believes

the very slight conformity of the testimony of widely separated sections contribute little or nothing to a demonstration which can be established or disproved probably only by a rigorous discussion of homogeneous material from a limited number of *long records*. Great importance attaches to the testimony of *long* records. Numerous stations or wide extent of territory can not make up for brevity in length of record. It is well known that warm and cold winters, for example, wet and dry seasons, in fact, all striking features of weather sequences, are not confined to single States but in general embrace very extended areas. The maps published by the Bureau for many years showing departures from normal often show in a striking way the widespread extent of marked anomalies in weather conditions. The presence of these anomalies give position and amplitude to the features in Mr. Alter's curves.

The concurrence of similar features in short records from numerous stations, or contiguous States even, are simply expressions of the similarity of weather conditions over the region in question. Even the semblance of similarity which Mr. Alter seems to believe marks the records for all the States of the United States has very little significance if based on relatively short records as is the actual case. We know from the control of the laws of chance that such similarities are inevitable, and nothing but the persistence of features in very long records suffices to establish the realty of alleged cycles which are so obscure and uncertain as the one which Mr. Alter claims is a possible case.

The occurrence of anomalies can be explained without resort to cosmical or extra-terrestrial causes. A very slight study of such questions long ago convinced the specialists of the Bureau that the cause of the major as also of many of the minor anomalies in question is practically always associated with varying features of the general circumpolar circulation of the atmosphere. It is true the full explanation of these seemingly fundamental connections can not be stated, and records suitable for critical investigation thereof are short and incomplete. In any case, it is irrational to claim or intimate that there is any significant relation between rainfall and sun-spots unless it is clearly demonstrated that the variations in the general circulation of the atmosphere which are known to modify greatly and to determine sequences of rainfall are themselves proven to be controlled by sun-spot conditions or intimately correlated thereto.

For these reasons little is added to a demonstration like Prof. Alter's by the great bulk of data discussed except possibly to fix somewhat more definitely very uncertain magnitudes inherent to short records. Only features which persistently stand out in *very long records*, even if such apply to only a limited area, are likely to be real.

The writer expects to present in a subsequent paper a number of fundamental propositions supported by graphic and mathematical criteria which may be employed to segregate abstractly in a convincing way cycles or sequences which are real from those which are specious or the result of fortuitous combinations.

METEOROLOGICAL COURSE GIVEN IN THE SIGNAL CORPS SCHOOL AT CAMP ALFRED VAIL, N. J., DURING 1920.

By HOMER W. BALL, Meteorologist.

[Weather Bureau, Royal Center, Ind., Feb. 10. 1921.]

[NOTE.—During the war, the first attempt at giving meteorological instruction consisted in training a few soldiers at the regular stations of the Weather Bureau. In the spring of 1918, the Signal Corps School of Meteorology was organized at the Texas Agricultural and Mechanical College, College Station, Tex. About half of these men and those who were first trained at the Weather Bureau stations were sent overseas; others were sent to camps in the United States where meteorological stations were established.[1] After the war, when the meteorological personnel of the war time had been largely discharged, to continue the meteorological work, it was necessary to instruct those men who were then enlisting in the Army. The present Signal Corps School was established at Camp Alfred Vail, N. J., about January 1, 1920, with the meteorological instruction in charge of Mr. Homer W. Ball, the author of this article. Mr. Ball continued in charge of this work until January 1, 1921, when it was taken over by Capt. A. H. Thiessen, formerly of the Weather Bureau. The school is continuing its work and at present has about 40 students.—EDITOR.]

SYNOPSIS.

The Army, recognizing the necessity of having men training in meteorological work, to supervise and carry on such work in the military service, has established a course in meteorology in the Signal Corps School at Camp Alfred Vail, N. J. As this is the only school in the United States giving a vocational course in meteorology, the results included in a considerable period of time may be watched with great interest. To date a large majority of the men who took this course in the school are doing excellent work on the Signal Corps stations.

The school maintained by the Signal Corps at Camp Alfred Vail, N. J., is for the theoretical and practical training of officers and enlisted men in the branches of work that pertain to that division of the military service. The theoretical work given to the enlisted men is necessarily elementary because of the short length of time allowed the student to finish his course and also the previous school training of a very large percentage of the men is not sufficient for them to do advanced studying. Considerable stress is laid upon the practical requirements so that the men taking the courses will be able to do the work assigned them along the lines in which they have had instruction. The instructional work is under the supervision of men who have had long experience in the duties covered by the subjects that they teach and the courses of study are arranged so that the conditions under which the student receives training will be as nearly as possible like those he will experience when on field duty or those under which he will have to work in civil life if he still wishes to follow the lines of instruction received in the school. Many men enlist in the Signal Corps to take advantage of the opportunities offered by the school and after their term of enlistment is ended they can then return to civil life and put to use the things they have learned while in the Army.

One of the departments established in the school at its beginning is meteorology. During the late war it was at once recognized that a large number of the activities of modern warfare depends upon atmospheric conditions on the surface of the earth and also at a considerable altitude above it. The Army having a large number of trained meterorologists has a great advantage over the one that does not have them. When the United States entered the conflict men trained in meteorological work and available for the Army were rather scarce and it was necessary to take a number of experts from the Weather Bureau to form a nucleus for a meteorological service in the Signal Corps. A large number of men were trained

[1] Regarding the Signal Corps School of Meteorology at College Station see MO. WEATHER REV., December, 1918, pp. 560-562; *also* ibid., April, 1919, pp. 215-222. Regarding the instruction in meteorology in France, see ibid., December, 1919, pp. 870-871.